WHITE PAPER

Potential Residential Use of Shallow Groundwater at RFETS

The feasibility of using shallow groundwater for residential water supply was evaluated as part of an overall risk assessment associated with future land use and redevelopment of RFETS. The evaluation included a drawdown analysis of site groundwater data to determine whether a hypothetical domestic well, completed in the unconsolidated surficial and upper weathered bedrock deposits at RFETS, could sustain well yields to support a family of four persons. The analysis was conducted using an analytical groundwater model that simulates drawdown in a pumping well. These simulations were performed independently on 140 existing monitoring wells that are completed in the Quaternary alluvium/colluvium and/or the upper Cretaceous sandstone in the Arapahoe and Laramie Formations. These wells had also been pump or slug tested for their hydraulic properties. Simulated drawdowns were compared to the actual measured saturated thickness at the monitoring wells to ascertain whether it was physically possible to lower water levels to a reasonable fraction of the existing saturated thickness.

Residential Water Requirements

Drawdown simulations for a hypothetical residential well were based on the premise that indoor water use for a family of four is 260 gallons per day. This value was obtained via oral communication from the Denver Water Department and was determined from a study conducted in 1997 by the American Water Works Association. The study concluded that the average daily per capita water useage in the Denver Metro area is 65 gallons. The value was calculated from a total per capita water useage of 176.88 gallons that includes both indoor and outdoor use and from an outdoor water useage of 118.88 gallons.

The discharge rate used in the model simulations was based on the average pumping rate of nine monitoring wells that were pump tested at RFETS and which were completed in the Quaternary surficial deposits and/or the upper Arapahoe and Laramie sandstone. Nine wells fit these criteria and were used to calculate the average pumping rate. Pumping rates for these wells varied significantly from 0.07 to 12.06 gallons per minute. Histograms of the pumping rates were generated as part of a descriptive statistical analysis to ascertain which distribution best fit the data and also to indicate if any outliers were present. Both the raw data and the natural log-transformed data were plotted. Histograms are presented in Attachment A. Although discharge rates from only nine wells were used in this analysis, the data appear to more closely fit a log normal distribution than a normal distribution. The histogram of the log-transformed data also indicated that the low value (0.07) was probably an outlier with respect to those wells that had pump tests performed. Thus, this value was excluded from further analysis.

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Based on the log normal nature of the data, the geometric mean was used to estimate the mean of the pumping rates. The geometric mean of the pumping rates was calculated to be 2.03 gpm. To conservatively estimate pumping rates at the site, the lowest rate that statistically fell within the 95 percent confidence limit of the mean was used. This rate (1.83 gpm) was calculated using a one-sided lower confidence limit for a log normal distribution (Land, 1971 in Gilbert, 1987). The equation used to calculate this limit and the summary statistics for the pumping rates are presented in Attachment B.

Model Input Parameters

The length of time of pumping was calculated to be 2.4 hours which was the time required to pump 260 gallons per day at a rate of 1.83 gpm. The specific yield was assumed to be 0.20 and was based on information presented in the Hydrogeologic Characterization Report For the Rocky Flats Environmental Technology Site (1995) for the unconsolidated surficial deposits. The radial distance from the pumping well was assumed to 1.0 foot.

The hydraulic conductivity (K) was obtained from a database file of 140 wells that were previously pump or slug tested at the site. K values ranged from 4E-08 to 5E-02 cm/sec. Many of the wells that were field tested for K were analyzed using several different techniques. For example, wells that were slug tested were analyzed with Bouwer and Rice and Hvorslev methods. Wells that were pump tested were analyzed using Theis, Cooper/Jacob, Neumann, and Thiem techniques. K values from each of these analysis were averaged for each well.

Transmissivity (T) values for each well were calculated from the average hydraulic conductivity and from the average saturated thickness. The average saturated thickness was calculated from depth to water measurements that have been historically recorded during periodic monitoring events and from the total depth (TD) of casing data recorded during well construction. Water level measurements were obtained from the soil and water database file SWD and were average for the total record of measurement. TD data were obtained from a master database file and were joined in database query with the average water level depth to calculate the average saturated thickness for each of the 140 wells.

Drawdown Calculations

Drawdown in each well was simulated in an Excel spreadsheet using the Theis equation. Due to the limitations of the Theis equation for low T values (<8.5 gallons per day per foot (gpd/ft)) which equates to a K value of <8 4E-05 cm/sec for 10 feet of saturated thickness, drawdowns in wells with this T value or less were assumed to exceed the TD of the well. At T values <8.5 gpd/ft, the corresponding well function value, W(u) becomes small enough to cause the drawdown value to decrease. This phenomenon is illustrated in Figure 3 which shows that as T values decrease, drawdown increases up to a point. It is at this inflection point, where T = 8.5 gpd/ft, that drawdown begins to decrease and the equation can no longer realistically predict drawdown in a well.

A reasonable amount of drawdown was assumed to be 1/3 of the available saturated thickness at each well. This value was considered reasonable in light of potential well losses attributable to well inefficiencies. Without compensating for these well losses, the Theis analysis would tend to underestimate actual drawdown values. Available drawdown is also reduced by the depth at which a pump is set and by inaccuracies in the theoretical equation due to the unconfined nature of the groundwater system. Relatively large drawdowns, with respect to a thin water-bearing zone, infer that flow is non horizontal, thus violating a primary assumption inherent in the Theis equation. Thus, 1/3 of the saturated thickness was considered as a physical limit to drawing down a water supply well. The results of the simulation indicated that 46 wells or 33 percent of the total 140 wells could sustain pumping and supply a residential family of four persons with water.

The spatial distribution of these 46 wells is shown in blue on the attached plate. The plate indicates that the wells are uniformly distributed over a wide area at RFETS and do not appear to be clustered in any one location. The wells used for this evaluation represent approximately 13 percent of the total number of wells installed at RFETS.

References

Gilbert, R.O., 1987, Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold, New York, New York

EG&G Rocky Flats, 1995, Hydrogeologic Characterization Report for the Rocky Flats Environmental Technology Site

Attachment A

Figures

Figure 1
Histogram of Well Yields From Quaternary Surficial Deposits and Ka No. 1 Sandstone

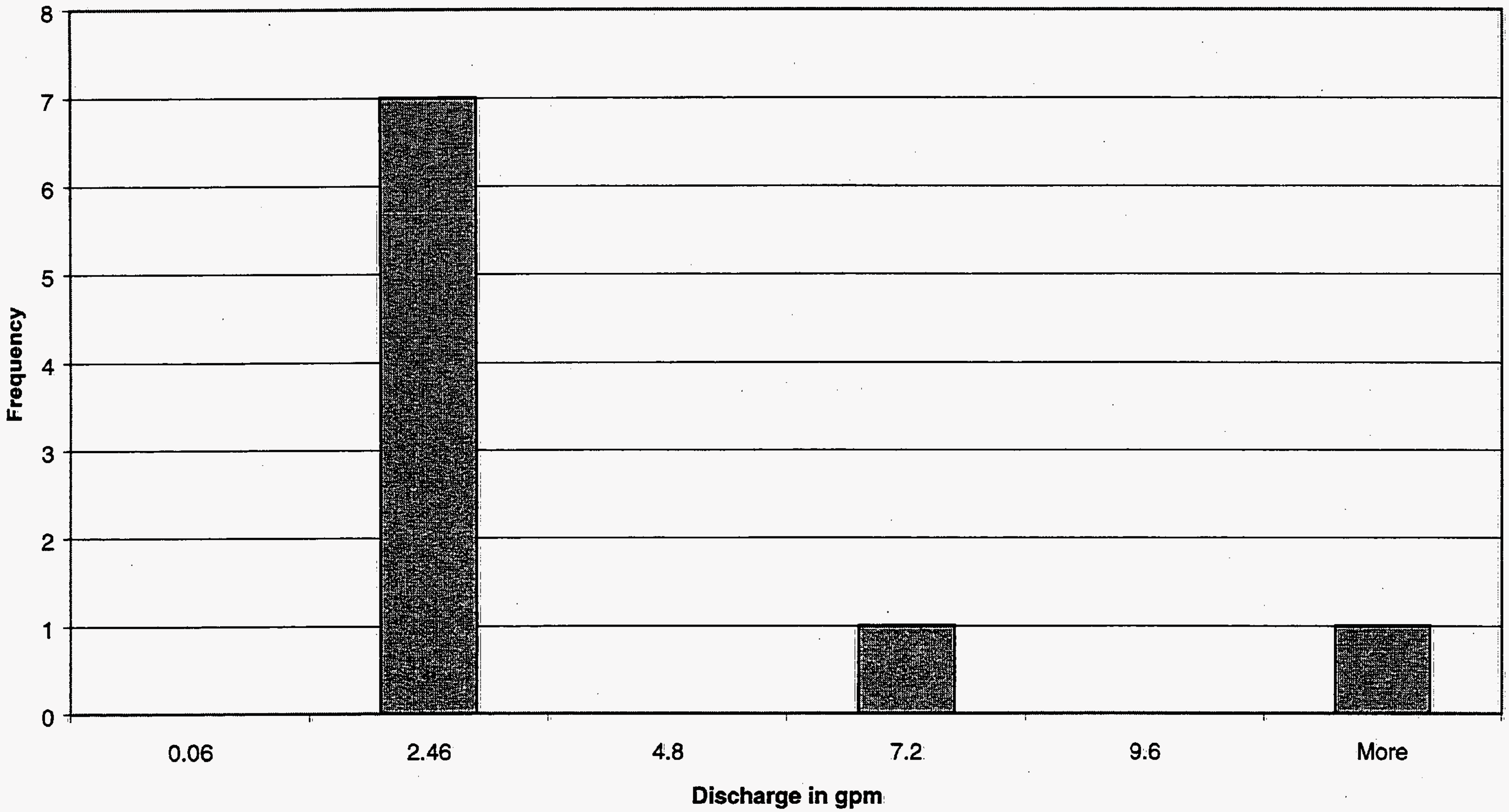


Figure 2
Histogram of Well Yields From Quaternary Surficial Deposits and Ka No. 1 Sandstone

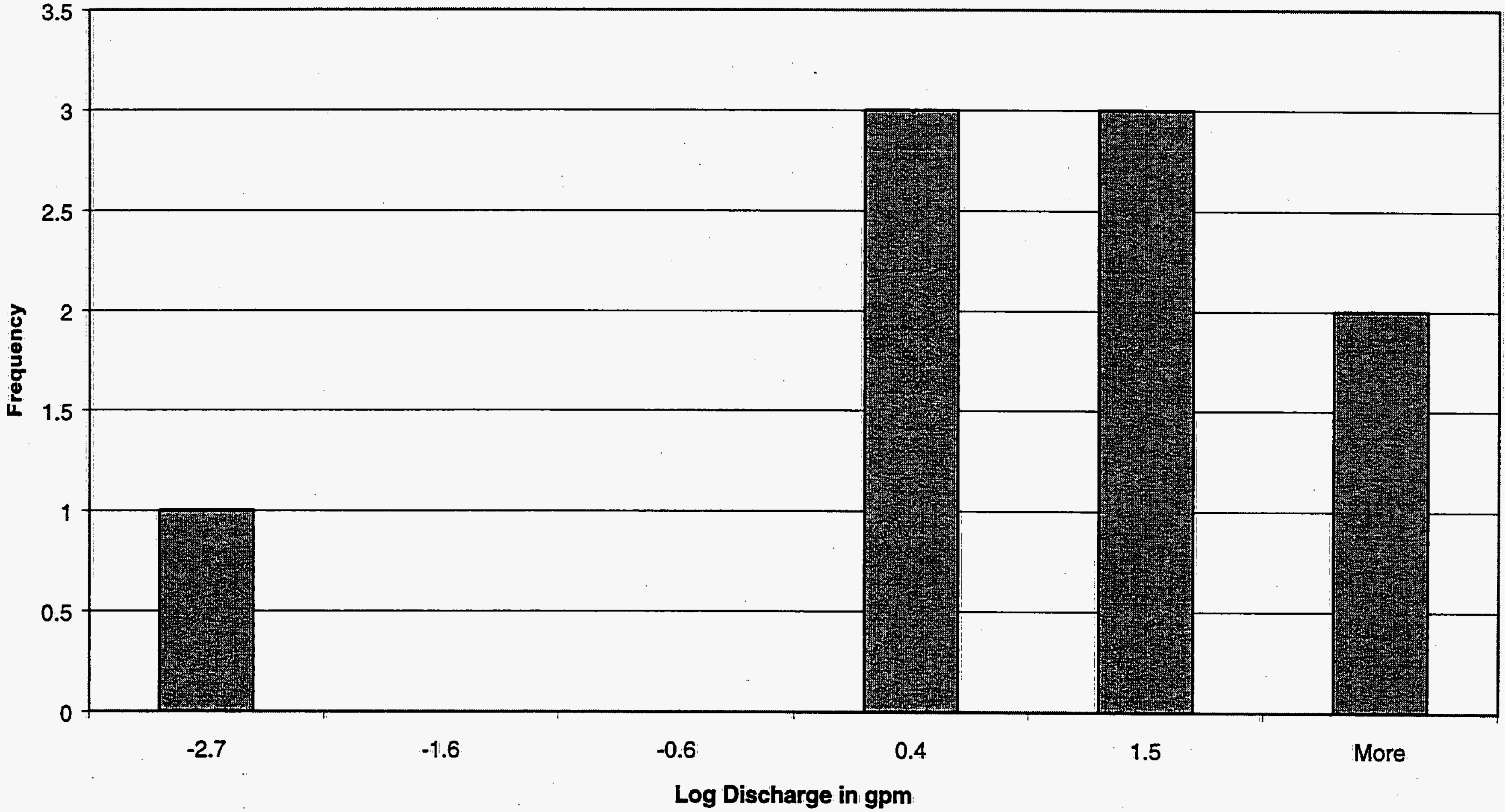
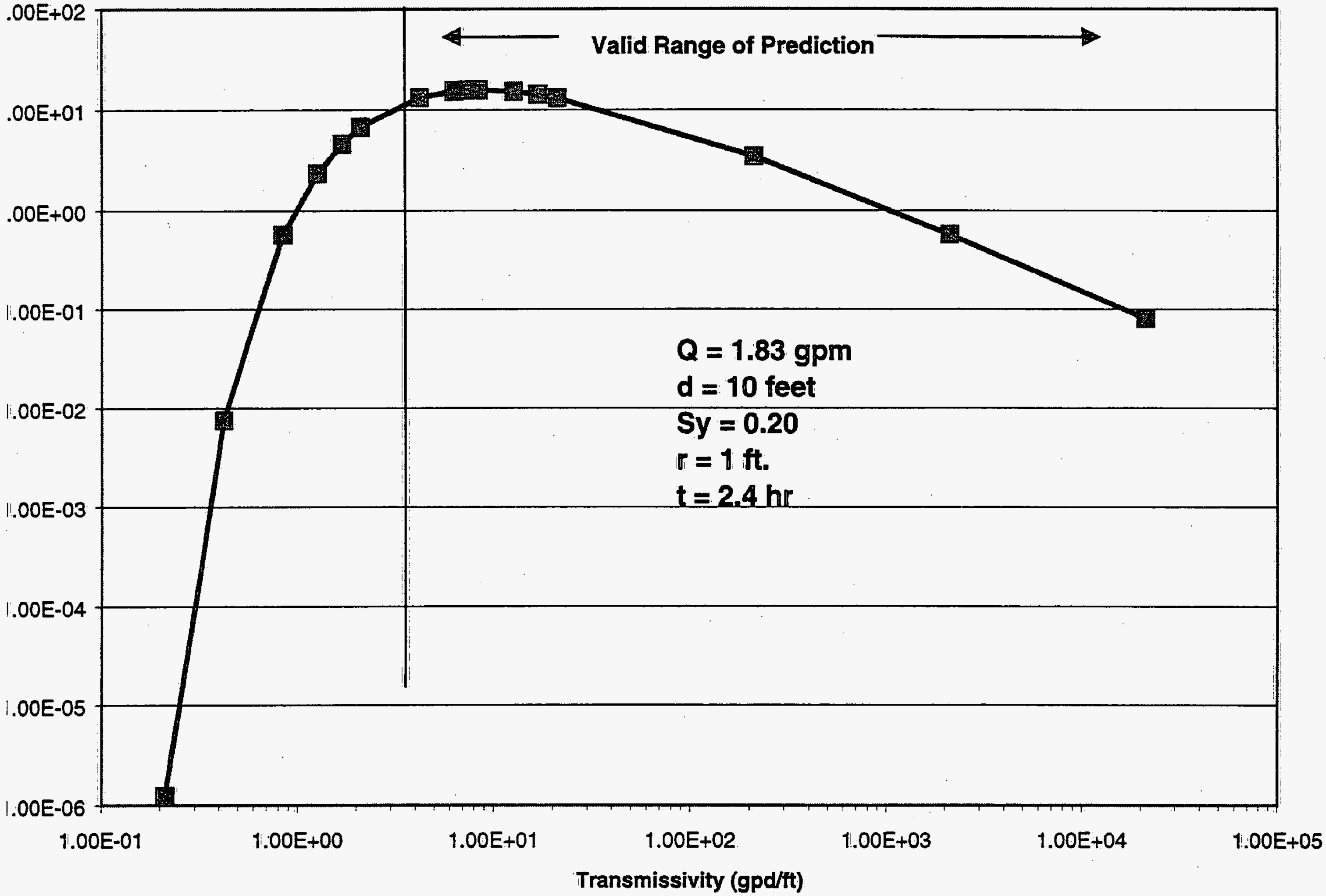


Figure 3
Drawdown Versus Transmissivity Using Theis Equation



Attachment B

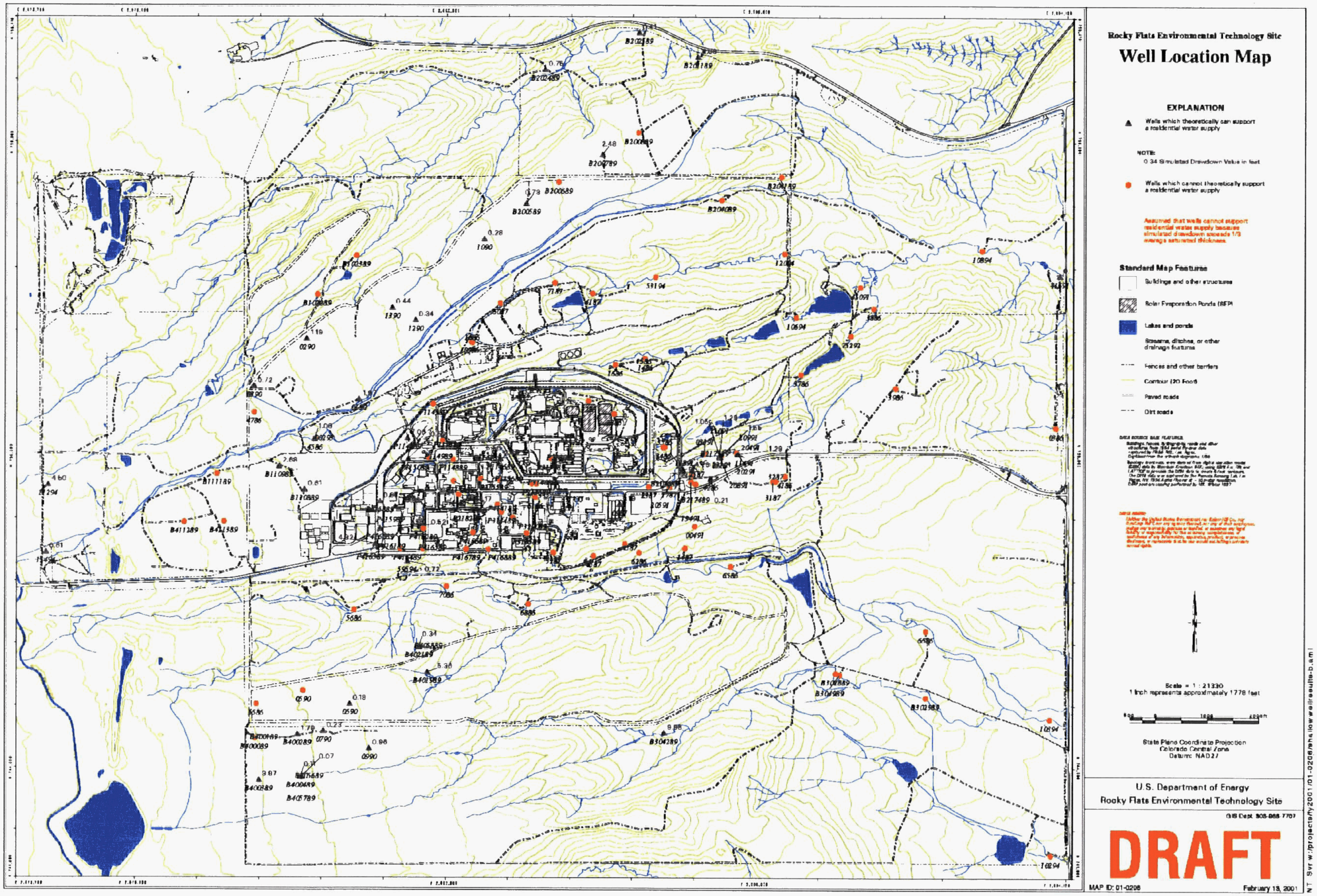
One sided confidence limit for a log normal distribution is given by the following equation:

$$LL_\alpha = \exp(\bar{y} + 0.5S^2y + \frac{S_y H_\alpha}{\sqrt{n-1}})$$

where:

LL_α = Lower confidence limit
$\bar{y}$ = Mean
S^2y = Sample variance
Sy = Standard deviation
H_α = 1.633 (Statistic from Table A13 in Gilbert, 1987)
N = Number of samples = 8

9/8



Rocky Flats Environmental Technology Site
Well Location Map
EXPLANATION
Wells which theoretically can support a residential water supply
NOTE:
0.34 Simulated Drawdown Value in feet
Wells which cannot theoretically support a residential water supply
Assumed that wells cannot support residential water supply because simulated drawdown exceeds 1/3 average saturated thickness
Standard Map Features
Buildings and other structures
Solar Evaporation Ponds (SEP)
Lakes and ponds
Streams, ditches, or other drainage features
Fences and other barriers
Contour (20 Foot)
Paved roads
Dirt roads
Scale = 1 : 21330
1 inch represents approximately 1778 feet
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27
U.S. Department of Energy
Rocky Flats Environmental Technology Site
DRAFT
MAP ID: 01-0208
February 13, 2001